NIOSH Response to SC&A Evaluation of SEC-00189 ORNL X-10 ORAUT-RPRT-0090

Response Paper

National Institute for Occupational Safety and Health

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BACKGROUND

In ORAUT-RPRT-0090, *Monitoring Feasibility Evaluation for Exotic Radionuclides Produced by the Oak Ridge National Laboratory Isotopes Division,* the National Institute for Occupational Safety and Health (NIOSH) evaluated the internal monitoring capability of Oak Ridge National Laboratory (ORNL) for "exotic radionuclides" produced by the Isotopes Division and its predecessors from 1955 to 1988 [NIOSH [2018].

In its evaluation, NIOSH listed 213 radionuclides as the final inventory for the Isotopes Division for the period 1955–1988, along with the corresponding years covered by the inventory, monitoring capability, and bioassay data availability. NIOSH found that ORNL had adequate monitoring capabilities for 179 of these 213 radionuclides. NIOSH then summarized the 34 remaining radionuclides needing additional evaluation.

PURPOSE AND SCOPE

In April 2018, the Advisory Board on Radiation and Worker Health (Advisory Board) tasked SC&A to evaluate ORAUT-RPRT-0090, Rev. 00. On October 9, 2018, SC&A issued its evaluation [Barton, et al. 2018]. SC&A reviewed the report regarding its general premise, the scope of its feasibility evaluation, and the adequacy and completeness of its review of monitoring capabilities and operational inventories. As a result, SC&A issued findings and observations needing clarification or further substantiation in terms of actual dosimetric practice and how that translates to demonstrated feasibility to monitor the wide range of exotic radionuclides, historically present in ORNL operations. This Response paper provides NIOSH's response to SC&A's findings and observations.

SC&A FINDING 1: THE SCOPE OF RPRT-0090 NEEDS TO BE CLEARLY DEFINED

SC&A finds that the scope of RPRT-0090 needs to be clarified in terms of whether (and how) it is meant to encompass the "reserved" portion of the ER for "cyclotrons, accelerators, and reactors" and whether NIOSH intends to address the full scope of radionuclides involved in waste management (including D&D), site-wide construction, and maintenance.

NIOSH Response:

The scope of ORAUT-RPRT-0090 was purposely limited to the production of radioisotopes by the Isotopes Division on both the ORNL and Y-12 footprints. The report evaluated the ability of ORNL to monitor for each radionuclide involved to determine if any represented such a challenge to the in-place monitoring program as to affect the ability to perform dose reconstruction. No such infeasibility was identified.

It should be noted that the entire period requested by the SEC-00189 petitioner (6/17/1943 – 7/31/1955) was qualified by NIOSH and addressed in the ORNL (X-10) evaluation report [NIOSH 2011]. As such, there is no portion related to that petition that remains to be evaluated. The evaluation of the "exotic radionuclides" was reserved in the SEC-00189 evaluation report due to the overlap between Y-12 and ORNL with respect to the calutron and cyclotron facilities and their associated operations. NIOSH decided to initiate a combined effort for Y-12 and ORNL to evaluate the isotopes production operations [NIOSH 2012]. Consequently, ORAUT-RPRT-0090 was developed to specifically address the ORNL isotopes production facilities to identify potential infeasibilities in the areas of the reserved section of the SEC-00189 evaluation report (as evidenced by the infeasibility for Pu-241 that was identified and addressed in a separate SEC evaluation). ORAUT-RPRT-0090 was not intended to be an evaluation of whether a co-exposure model type approach could be developed for every single radionuclide.

SC&A FINDING 2: INCOMPLETE RADIONUCLIDE AND RADIOISOTOPE FACILITY INVENTORY

A sampling of the radionuclides listed in Table 7-2 found a few missing when compared with operational and customer records. Likewise, a few ORNL facilities that historically handled radioisotopes are also not included in those cited and addressed in RPRT-0090. Given the operational diversity of ORNL accelerator and reactor operations, consideration should be given to an inventory scope that encompasses isotopic source terms broader than that of the Isotope Division.

NIOSH Response:

The discrepancies indicated by SC&A are generally related to the scope of the document, that is, the isotopes produced by the isotopes group versus a more general analysis of the overall radionuclide inventory at ORNL. The facilities listed in ORAUT-RPRT-0090 are the primary facilities used by the isotopes group and are presented for a historical perspective. The inventory listing was developed independently of the facility list and was related to isotope group activities across the site.

Specific discrepancies presented in Table 1 of SC&A's review (within the narrative associated with Finding 2) are addressed in Table 1 below.

Table 1. Review of "Example of Radionuclides Not Included in RPRT-0090"

SC&A Citation/ [NIOSH Citation]	Listed Nuclides	NIOSH Comments
ORNL 1957/ [Seagren 1957]	Europium-154 Iron-55, -59	• Europium-154 is listed in the cited report as 'Eu-152, Eu-154'. It was added to ORAUT-RPRT-0090 as Eu-152. Detection capabilities for Eu-152, which are addressed in ORAUT-RPRT-0090, would also apply to Eu-154; therefore, listing Eu-152/Eu-154 in this manner is inconsequential in regards to the conclusions drawn in ORAUT-RPRT-0090. However, ORAUT-RPRT-0090 will be revised for clarification. • Iron-55 and Iron-59 are listed in Table 7-2 for 1956, which is the year that the cited report [Seagren 1957] covers.
ORNL 1965/ [Baker 1965]	Lutetium-174 Iodine-128 Europium-149 Europium-154 Thulium-168	• Lutetium-174 is listed in the cited report as a 'special irradiation (cyclotron)'. • Iodine-128 is not listed in the cited report. • Europium-149 is listed in the cited report as 'special irradiation (cyclotron)'. • Europium-154 is listed in the cited report as 'Eu-152, Eu-154'. It was added to ORAUT-RPRT-0090 as Eu-152. Detection capabilities for Eu-152, which are addressed in ORAUT-RPRT-0090, would also apply to Eu-154 so listing Eu-152/Eu-154 in this manner is inconsequential in regards to the conclusions drawn in ORAUT-RPRT-0090. • Thulium-168 is listed in the cited report as 'special irradiation (cyclotron)'. • Note: 'special irradiation' designates that ORNL was only responsible for target irradiation and that processing was performed off-site.
BNWL 1977/ [Simmons 1977]	Europium-154	• Europium-154 is listed in the cited report as 'Eu-152, Eu-154'. It was added to ORAUT-RPRT-0090 as Eu-152. Detection capabilities for Eu-152, which are addressed in ORAUT-RPRT-0090, would also apply to Eu-154 so listing Eu-152/Eu-154 in this manner is inconsequential in regards to the conclusions drawn in ORAUT-RPRT-0090. Note: Eu-154 was listed in the cited report with an annotation of (I), indicating that it was provided by INEL.
PNL 1984/ [Baker 1984]	Aluminum-26	• Aluminum-26 is listed in the cited report with a supplier code of 'L', indicating that LANL provided the material. As such, the citation is not indicative of material processed by ORNL.
Kohring 1990/ [Kohring 1990]	Chlorine-34 Manganese-57 Iodine-128 Europium-154	• The cited report is a site-wide inventory of radionuclides present and not an indication of production by the isotopes group, which was the subject of ORAUT-RPRT-0090. A clarification on the scope will be added to a revision of ORAUT-RPRT-0090.

SC&A FINDING 3: ATTACHMENT A *IN VITRO* BIOASSAY METHODS LACKS INFORMATION ABOUT ACTUAL IMPLEMENTATION

In vitro *bioassay methods are outlined in Attachment A, but it does not include any discussion or references regarding their actual field implementation. The exclusion of comparable* in vivo *monitoring methods makes a review of ORNL monitoring capability incomplete.*

NIOSH Response:

NIOSH intends ORAUT-RPRT-0090 to be a review of the isotopes handled by the isotopes production group in comparison to the available bioassay capability. The report provides a detailed listing of bioassay availability by indicating the number of measurements performed for each method discussed in Attachment A. The available number of bioassay records indicates that the available methods were implemented according to the policies in place at the time. A monitoring method would not be expected to be broadly implemented if the given radionuclide was only produced sporadically. It is not clear what additional information would be needed to rule out a potential dose reconstruction infeasibility. Note that not all available data on sporadically-produced radionuclides will be a sufficient quantity to allow for their use in a co-exposure model. However, this alone is not indicative that a potential exposure could not be bound with sufficient accuracy.

SC&A FINDING 4: FEASIBILITY OF MONITORING 28 RADIONUCLIDES NOT ADEQUATELY ADDRESSED

While the 28 radionuclides were discussed in Section 7.2 and some of their characteristics were listed in Tables 7-4, 7-5, and 7-6 of RPRT-0090, the feasibility of monitoring for intakes for DR purposes was not completely addressed, particularly given the lack of routine bioassays in the earlier years. Methods for accounting for the lack of monitoring of these radionuclides need to be addressed in more detail, and an acceptable resolution derived. SC&A finds that it is not possible at this time to validate implementation without further onsite review, including document review and interviews with health physicists of the time period involved.

NIOSH Response:

The implementation of the monitoring program is indicated by the availability of the bioassay cards showing results for the respective methods. Any available bioassay data could be used to assign doses to a claimant using an individual dose reconstruction approach and the methods established in the site profile. Additional review of available records on monitoring procedures will be on-going using the data available in the Site Research Data Base (SRDB); SC&A is invited to do the same (current holdings for ORNL are close to 15,000 documents). NIOSH did not intend to include a formal review of program implementation in ORAUT-RPRT-0090

because that was not the objective of the report (see also the response to Finding 3).

SC&A FINDING 5: 1955 AND 1956 INTAKES MAY NOT BE BOUND BY EARLIER COWORKER DATA

Assessment of RaLa radioiodine releases at X-10 indicates the highest annual releases occurred during the campaign to process Hanford slugs during 1956. Therefore, the radioiodine production and releases during the years used for coworker development (1947–1949) do not appear to bound the production throughput, at least during 1956 and possibly 1955.

NIOSH Response:

NOTE: NIOSH now uses the term "co-exposure" for coworker or co-worker. Verbatim quotes from documents issued by other organizations retain their terminology.

There is no doubt that the incidental release of iodine during RaLa production and releases during the production of iodine are different. The salient point is that an individual who received no thyroid monitoring from 1955 to 1962 would not likely have been exposed to a higher level of radioiodine than that determined by a chronic intake using the 95th percentile of routine monitoring data for 1947 to 1949. This conclusion is supported by the fact that during the earlier period (1947–1949) much larger quantities of iodine were processed than during the 1955–1962 activities of the isotopes group (1,000 ci – 3,600 Ci). The minimum annual inventory during the 1947 to 1949 period (8,800 Ci/yr) is based on the range of 8,800 Ci/yr to 42,600 Ci/yr [ATSDR 2008, PDF p. 16]. The fact that the cited quantity might only represent the quantity released through stack emissions provides further support since the stack emissions would be much smaller than the quantity of material being processed.

The assertion that the intake calculated at the 95th percentile based on monitoring performed from 1947 to 1949 is somehow not sufficiently claimant favorable fails to consider the intended use of the co-exposure (formerly coworker) data to address potentially unmonitored exposure to isotopes group workers. Moreover, to accept this one would have to conclude that the release quantity tabulated for 1956 (66,700 Ci) is sufficiently higher than the value cited for 1947 (64,200 Ci) to not be within the uncertainty inherent in the data itself and not addressed by the use of the 95th percentile of the intake calculated using the 1947 – 1949 data. In fact, these values differ by less than 4% [ATSDR 2008, PDF p. 12].

In the narrative preceding Finding 5, a number of concerns were documented. To assist in the understanding of the ORAUT approach, additional clarification specific to each concern is provided in Table 2 below.

Table 2. SC&A concerns related to Finding #5

No.	Stated Concern	Clarifications
1	Of the 168 bioassay samples evaluated in RPRT-0090, only 8 were taken prior to 1963 and only 2 were taken prior to the first use of the whole body counter (WBC) in 1961.	As stated in section C.4, the evaluation of iodine exposure prior to 1962 was primarily done using thyroid monitoring. A total of 230 such measurements are available spanning the period 1945 through 1957.
2	Although RPRT-0090 notes that the projected urinary excretion rate is more than an order of magnitude higher than the maximum observed routine sample, no information or references are provided to indicate when that routine sample was taken. The analysis in Section C.7 of RPRT-0090 indicates that the evaluated urinalysis results spanned all the way to 1988.	The maximum observed routine sample cited was collected on 11/4/1966 [ORNL 1986, PDF p. 3]. This sample was one of the 115 iodine urine samples coded as type '000' in the ORNL bioassay records (see ORAUT-RPRT-0090, Table 4-3).
3	Per Table C-8 of RPRT-0090, the highest observed radioiodine urinalysis sample was 2.2×10^{7} picocuries per day (pCi/d), which is a factor of 130 higher than the projected urinary excretion rate using the chronic co-exposure model. NIOSH indicates this sample was categorized as "incident/follow-up/resample" but does not elaborate on the timeframe or conditions.	The referenced sample was collected on 6/22/1967. The sample is related to an event that occurred on 6/21/1967 and is detailed in section C-11 of ORAUT-RPRT-0090 in the subsection pertaining to that incident date.
4	Conclusion 2 notes that the projected whole-body accumulation is a factor of 4 larger than the highest whole-body accumulation recorded (0.28 microcuries [μCi]). However, this whole-body measurement was made in 1962, and no whole-body measurements were made until 1961. It has not been established that these data can be back-extrapolated to represent prior exposure conditions.	The intention of the cited comparison (i.e., "factor of 4 larger than the highest whole-body accumulation recorded") is to contrast the expected accumulation (based on the claimant-favorable proposed intake quantity during the period in which it would be applied) to the magnitude of the actual measured quantity during the period during which that proposed claimant favorable intake would be applied. This is done to indicate that the proposed intake is bounding. That is, projections based on the proposed intake are much higher than anything actually observed in the exposed population.
5	Conclusion 3 notes that the projected chronic air concentration (1.8×10^{-8} μCi/cm^3) was nearly a factor of 2 higher than the maximum operating level used to control facility air concentrations. However, the air sampling data are only available in summary form, and neither the quantitative results nor the locations of these air samples are currently known.	The comparison was to the operating limits (tolerance values) enforced during the time period, not the actually observed air concentrations. The point made is that the air concentrations above what would be allowed for routine occupancy would be associated with the magnitude of intakes proposed for assignment to unmonitored individuals.

No.	Stated Concern	Clarifications
6	The ORNL site profile (NIOSH 2007, p. 34) notes that the tolerance-level air concentration during 1954 (the year just prior to the unmonitored period of interest) was actually 3×10^{-8} μCi/cm^3, 50% higher than the projected air concentration calculated in RPRT-0090 (1.8×10^{-8} μCi/cm^3).	The documents associated with the citation in NIOSH 2007, p 34 referred to the 'tolerance level' anecdotally without specifying the actual tolerance value. The tolerance value applicable to beta/gamma air concentration data is 1 x 10^{-8} μCi/cm^3 as indicated in the 5/1/1951 compilation of maximum permissible operating levels [Sadowski 1953, PDF p. 7]. The cited value of 3 x 10^{-8} is in error and will be corrected in the next revision of the ORNL site profile

SC&A FINDING 6: ADEQUACY AND IMPLEMENTATION OF *IN VIVO* BIOASSAY PROGRAM NOT ADDRESSED

Information is lacking for the actual implementation of the ORNL in vivo *program, including what and how radionuclides were monitored in practice, what and how workers were identified and included for counting, and how capability to monitor for MAPs, MFPs, and exotic radionuclides paced both technology developments and onsite monitoring practice (e.g., routine vs. non-routine monitoring). SC&A recommends that the Work Group request a review of available records, particularly internal dosimetry program records, WBC nuclide libraries, and scheduling of interviews with appropriate ORNL dosimetry staff.*

NIOSH Response:

NIOSH believes that the volume of available monitoring data, including analysis for non-routine radionuclides, as shown in ORAUT-RPRT-0090, Table 4.3 (Bioassay code 000 with monitored nuclide, 1955 – 1988), demonstrates the capability to monitor exposure to the wide range of materials present. However, NIOSH did not intend to include a review of program implementation in ORAUT-RPRT-0090.

There are numerous internal dosimetry related documents already available in the SRDB that SC&A may review prior to additional data captures and interviews (the current SRDB holdings for ORNL amount to almost 15000 documents). These include excerpts from radiological control personnel logbooks, which demonstrate the level of control and monitoring performed.

SC&A FINDING 7: UNCLEAR TREATMENT OF POST-1988 MONITORING CAPABILITY DURING ABANDONMENT, DEACTIVATION, AND DECONTAMINATION AND DECOMMISSIONING PHASES

After radionuclide production ended, the adequacy of monitoring and feasibility of assigning intakes from the storage, disposal, and D&D of the facilities has not been addressed. This issue is especially important for the ORNL Isotopes Division because it processed and concentrated unusual radionuclides that would not be encountered during the normal D&D process.

NIOSH Response:

The point of ORAUT-RPRT-0090 was to assess the feasibility of monitoring nuclides produced by the isotopes group during production operations. While such analysis is outside the scope of the document, it would seem credible that it would be feasible to bound exposures to the same set of radionuclides during D&D periods after 1988 with modern dosimetry methods.

SC&A OBSERVATION 1: INVENTORY DISCREPANCY

A sampling of some of the inventory of the radionuclides for the early years indicated some discrepancies in inventory between Table 7-2 in RPRT-0090 and NIOSH's X-10 Inventory spreadsheet.

NIOSH Response:

As stated in section 6.0 of ORAUT-RPRT-0090, an inventory of radionuclides processed by the ORNL X-10 isotopes group was developed through a review of published sales records. The spreadsheet that SC&A refers to in their comment represents the compilation of that document review. However, as also indicated in section 6.0, NIOSH updated the radionuclide inventory based on a review of logbooks. This review resulted in the addition of additional radionuclides, and additional inventory years for existing radionuclides.

In regards to the comparison of radionuclides identified through the summary of monitoring data contained in ORAUT-TKBS-0012 and the inventory data contained in ORAUT-RPRT-0090, it should be noted that the scopes of these documents are different and that ORAUT-RPRT-0090 is limited to the inventory of materials processed by the isotopes group and not the inventory of all radionuclides potentially present at ORNL.

SC&A OBSERVATION 2: SPECIFIC ALPHA-EMITTING RADIONUCLIDE NEEDS TO BE IDENTIFIED FOR DR

The specific radioisotope monitored is not always presented in NIOSH's X-10 Database as it generally is in the NOCTS files. Gross alpha results could be applied to many radionuclides. Is the information on the original bioassay cards available in the X-10 Database, and will the X-10 Database be used in DR or coworker model development?

NIOSH Response:

The original X-10 bioassay cards are provided by ORNL for individual claimants and are the basis for dose reconstruction. The X-10 database is not used for dose reconstruction purposes. Any notations as to the specific radionuclide being monitored are available for use in the claimant-specific dose reconstruction report.

SC&A OBSERVATION 3: TRANS-PLUTONIUM RADIONUCLIDES MAY NEED FURTHER ANALYSES

SC&A is concerned that assigning trans-plutonium gross alpha counting results as Am-241 intakes without consideration of other potential trivalent alpha-emitting actinides (such as Bk-249, Cf-252, Cm-242, Cm-244, etc.) and their individual radiotoxicity could result in underestimating the internal dose. It could be beneficial to determine if assigning the intake as Am-241 is claimant favorable, considering the exotic trans-plutonium radionuclides at ORNL.

NIOSH Response:

ORAUT-TKBS-0012-5 (Oak Ridge National Laboratory – Occupational Internal Dose) identifies Am-241 as the default assumption for the interpretation of trans-plutonium (TPO) bioassay results. However, individual dose assessments are completed considering all available claimant-specific information, including any data. This includes the original bioassay cards, which, along with other information contained in the claimant records, may contain identifying information on the nuclides of interest. Of the 20 radionuclides that are called out in ORAUT-RPRT-0090 as detectable by the TPO method, only two have a higher organ dose conversion factor (DCF, dose to a particular organ/unit activity). These are Cm-248 and Cf-249 with maximum organ DCF ratio to Am-241 of 3.7 and 1.55, respectively. However, Am-241 is a reasonable default assumption considering that the maximum annual inventory for these two radionuclides (64 mCi and 56 mCi, respectively) is a factor of 10^5 lower than that of Am-241.

SC&A OBSERVATION 4: USE OF GROSS BETA OR GAMMA COUNT DATA COULD RESULT IN AN UNDERESTIMATE OF ASSIGNED DOSE

Using gross beta or gamma count data without knowledge of the radionuclide the counter was calibrated with and the radionuclides in the bioassay sample could result in assigning the incorrect radionuclide and radioactivity content because of different counting efficiencies for the different energy of beta particles and gamma photons. Has this issue been addressed for DR for ORNL claimants? Additionally, bioassay data for at least one beta-emitting radionuclide (Ru-106) could not be located for several years that Table 7-2 indicated it was available.

NIOSH Response:

In regards to the issue with Ru-106, bioassay methods assigned to Ru-106 are type 000 (Ru-106), 013/GB0, and RU6. SC&A is correct in that, although Table 7-1 shading is 'green' indicating the presence of bioassay data, no results for these methods were present in 1975, 1978, and 1986-1988. An editing mistake happened during the final document preparation for 508 compliance. In the next revision to ORAUT-RPRT-0090, Table 7-2 will be shaded 'yellow' for the indicated years.

The original X-10 bioassay cards are provided by ORNL for individual claimants and are the basis for dose reconstruction. Any notations as to the specific radionuclide being monitored are available for use in the claimant-specific dose reconstruction report. Specific adjustments based on individual radionuclides would be outside the scope of ORAUT-RPRT-0090 and would be addressed within individual dose reconstruction reports, if appropriate.

SC&A OBSERVATION 5: THE RESULTS IN TABLE 7-6 DEPEND ON INVENTORY USED

As outlined in Observation 1, there appear to be some discrepancies in the inventory used by NIOSH compared to those provided to SC&A for evaluation of RPRT-0090. These discrepancies change a few of the results of Table 7-6, as illustrated in Table 3 of this report.

NIOSH Response:

As indicated in the response to Observation 1, the spreadsheet upon which SC&A's comparison is based contained only the results of the review of Isotope Group sales/inventory data.

Additional research was conducted for radionuclides contained in Table 7-6 when for one or more years are 'unknown'. Additional information on the identified radionuclide inventory discrepancies is provided in Table 3, below.

Table 3. Additional information on radionuclides identified in Table 7-6

Radionuclide	Comments
Strontium-85	The inventory amount from a spreadsheet provided to SC&A and used in the report was 142 mCi for 1958. The value cited by SC&A is for 1957.
Molybdenum-93	Inventory amount from a spreadsheet provided to SC&A and used in the report was unknown in 1957 and 39 mCi for 1962. Since one or more inventory values were unknown, the overall value indicated is 'unknown' in ORAUT calculation, SC&A cites the 1962 inventory value in their calculations.
Palladium-103	The inventory amount for Pa-103 was unknown in 1964 and 47.5 mCi for 1962. Since one or more inventory values were unknown, the overall value indicated is 'unknown' in ORAUT calculation, SC&A cites the 1962 inventory value in their calculations.
Tellurium-121	The inventory amount listed in the inventory spreadsheet provided to SC&A is unknown. Additional research was conducted and determined that production "for research use" was performed in 1957 at ORNL (Livingston, 1958, PDF p. 18). No quantity information is available. The 13-mCi value cited in Table 7.6 is in error and will be corrected at the next revision to ORAUT-RPRT-090.
Cesium-131	The inventory amount from the Ba-131 parent was used.
Promethium-145	Inventory amount from Isotopes Development Center Newsletter for December 1967 [Rupp 1968, PDF p. 4].
Tungsten-181	Inventory amount based on data in Livingston [1958, PDF p. 18; 1959, PDF p. 22].

SC&A OBSERVATION 6: ADDITIONAL RaLa PRODUCTION INFORMATION SHOULD BE PROVIDED

NIOSH should provide an evaluation and discussion of any potential differences in exposure potential between commercial radioiodine production and the radioiodine produced via the RaLa operation to justify the extrapolation of exposures occurring during the years 1947–1949 to the unmonitored period (1955–1962).

NIOSH Response:

NIOSH believes that the exposure routes from RaLa processing and commercial iodine production are not relevant to the analysis presented. Both sets of activities were subject to the same radiological protection and monitoring programs. It is not likely that unmonitored individuals working from 1955 to 1962 would be exposed to levels of activity that would have triggered the monitoring program, as demonstrated by the fact that individuals exposed to such levels were in fact monitored during the period for which monitoring data are available (1947–1949).

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